Enhancements to IMERG in Version 06

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THE CURRENT GPM MICROWAVE CONSTELLATION

The original goal was 3-hourly observations, globally

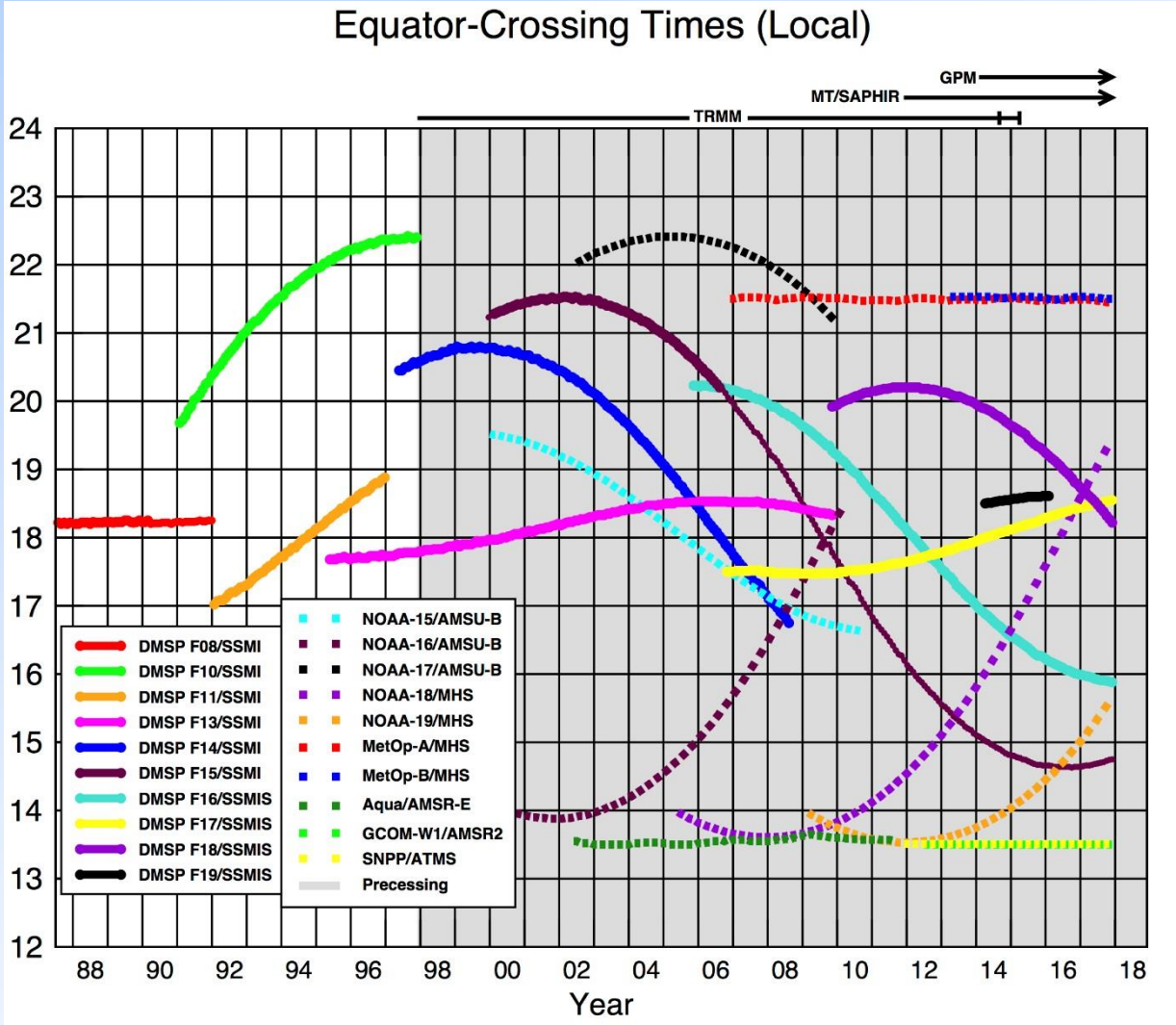
- Original basis was sampling the diurnal cycle
- But also, morphed microwave loses skill outside ±90 minutes

The current IMERG constellation includes:

- 5 polar-orbit passive microwave imagers
  - 3 SSMIS, AMSR-2, GMI
- 5 (4?) polar-orbit passive microwave sounders
  - 4 (3?) MHS, ATMS

IMERG roots

- Kalman Filter CMORPH – CPC/NOAA
- PERSIANN with Cloud Classification System – U.C.-Irvine
- TMPA – GSFC NASA
- Precipitation Processing System (PPS, GSFC/NASA)
- IMERG is a single integrated code system appropriate for near-real and post-real time



Ascending passes (F08 descending); satellites depicted above graph precess throughout the day.
Image by Eric Nelkin (SSAI), 14 December 2017, NASA/Goddard Space Flight Center, Greenbelt, MD.

ADJUSTING GPM CORE PRODUCTS TO GPCP (OCEAN)

GPM Core products are low in the extratropical oceans

Ocean-only zonals for 2015

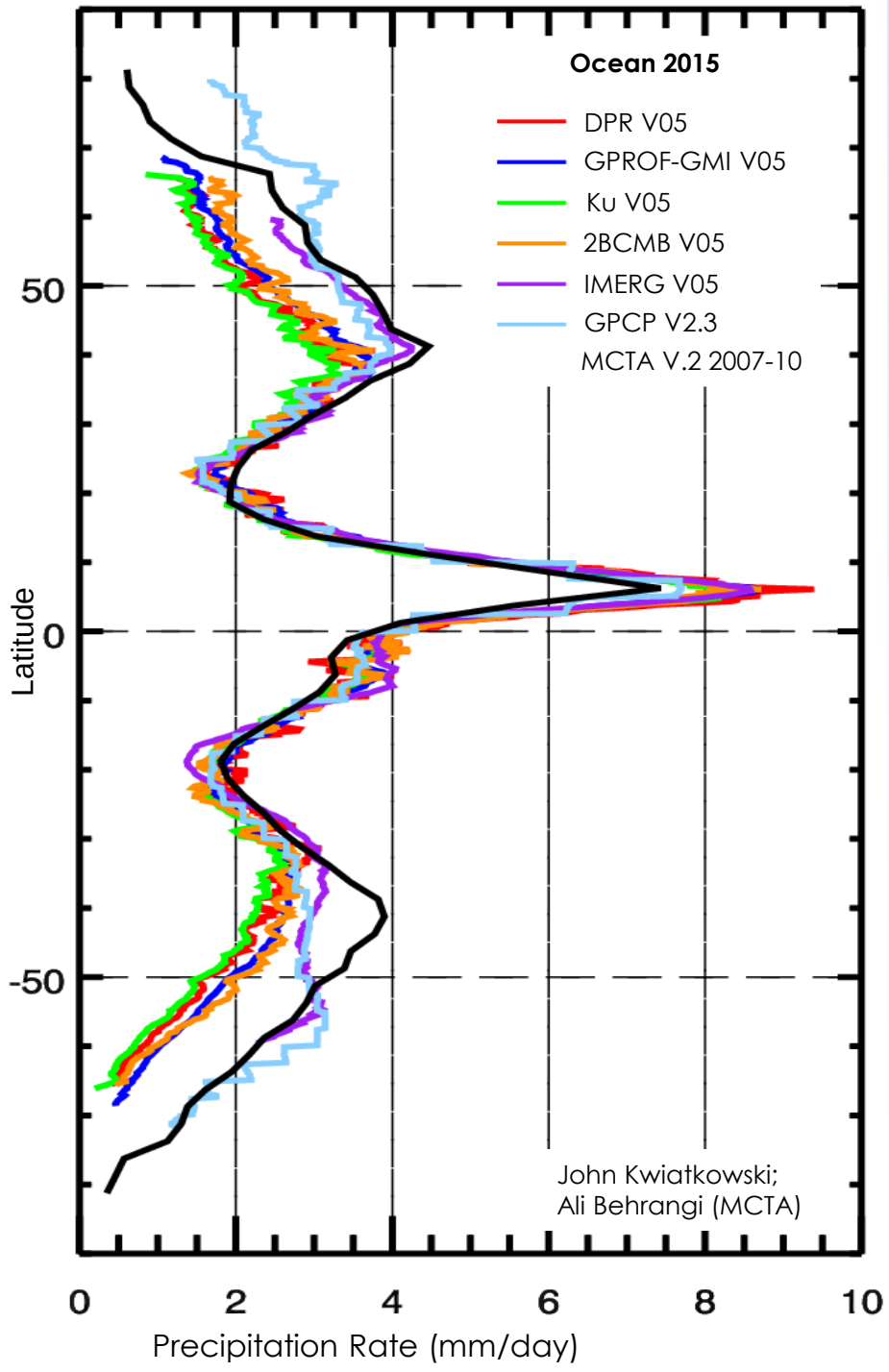
V05 GPM core products are similar, by design

GPCP is higher in the extratropics

- Version 2.3 of community standard
- Behrangi Multi-satellite CloudSat, TRMM, Aqua (MCTA) product confirms GPM bias
  - includes CloudSat rain, snow, mixed
  - higher than GPCP in mid-latitudes
  - roughly agrees at high latitudes

Adjust IMERG V04, V05, and now V06 to GPCP at higher latitudes with seasonal "climatology"

- provides reasonable IMERG bias in V04
- low biases in GPM products addressed in V05, but still low, still require GPCP



ADJUSTING GPM CORE PRODUCTS TO GPCP (LAND)

GPM Core product biases vary by latitude over land

Land-only zonals for 2015

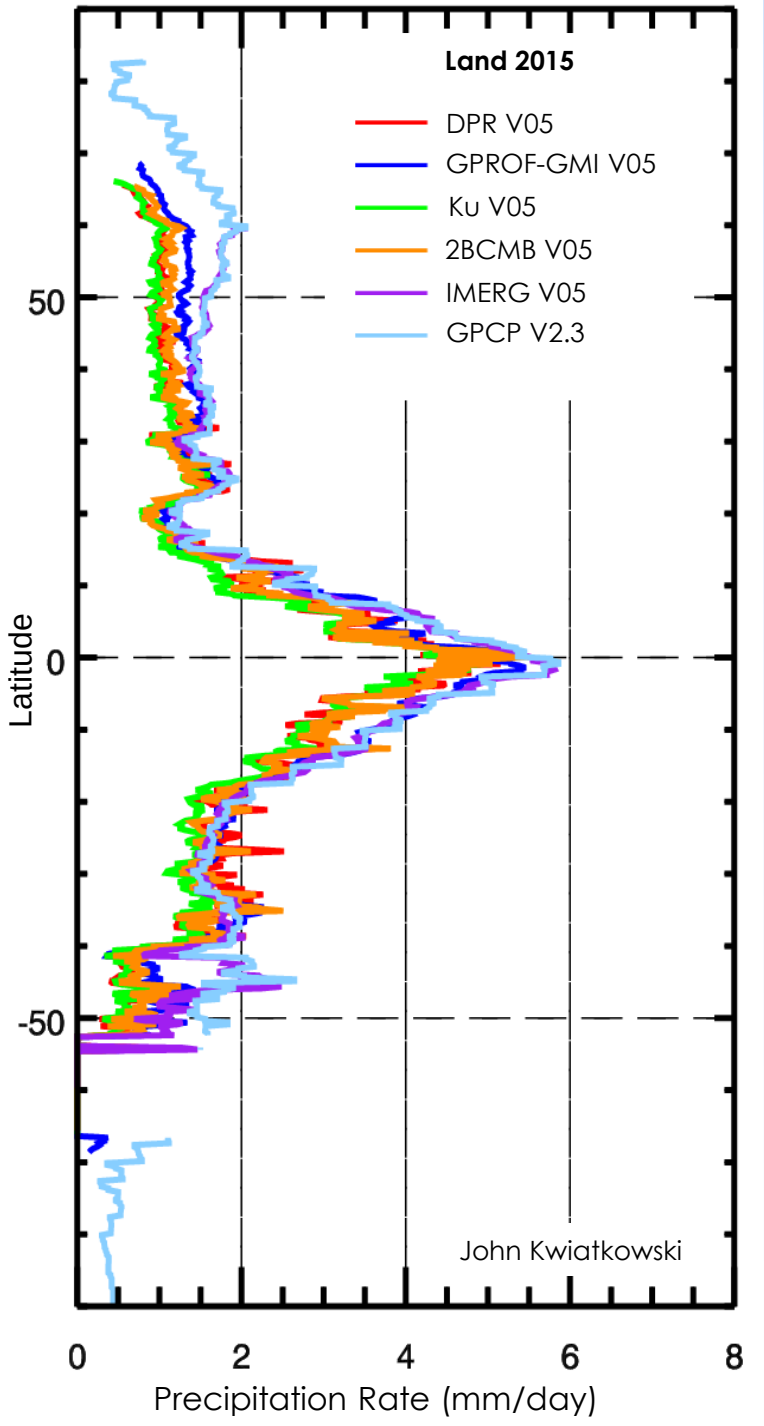
V05 GPM core products tend to show more spread

GPCP is higher in the extratropics

- V05 IMERG similar (both use GPCC gauge analysis)
- MCTA n/a over land

Adjust IMERG to GPCP for V04, V05, and now V06 at all latitudes with a seasonal "climatology"

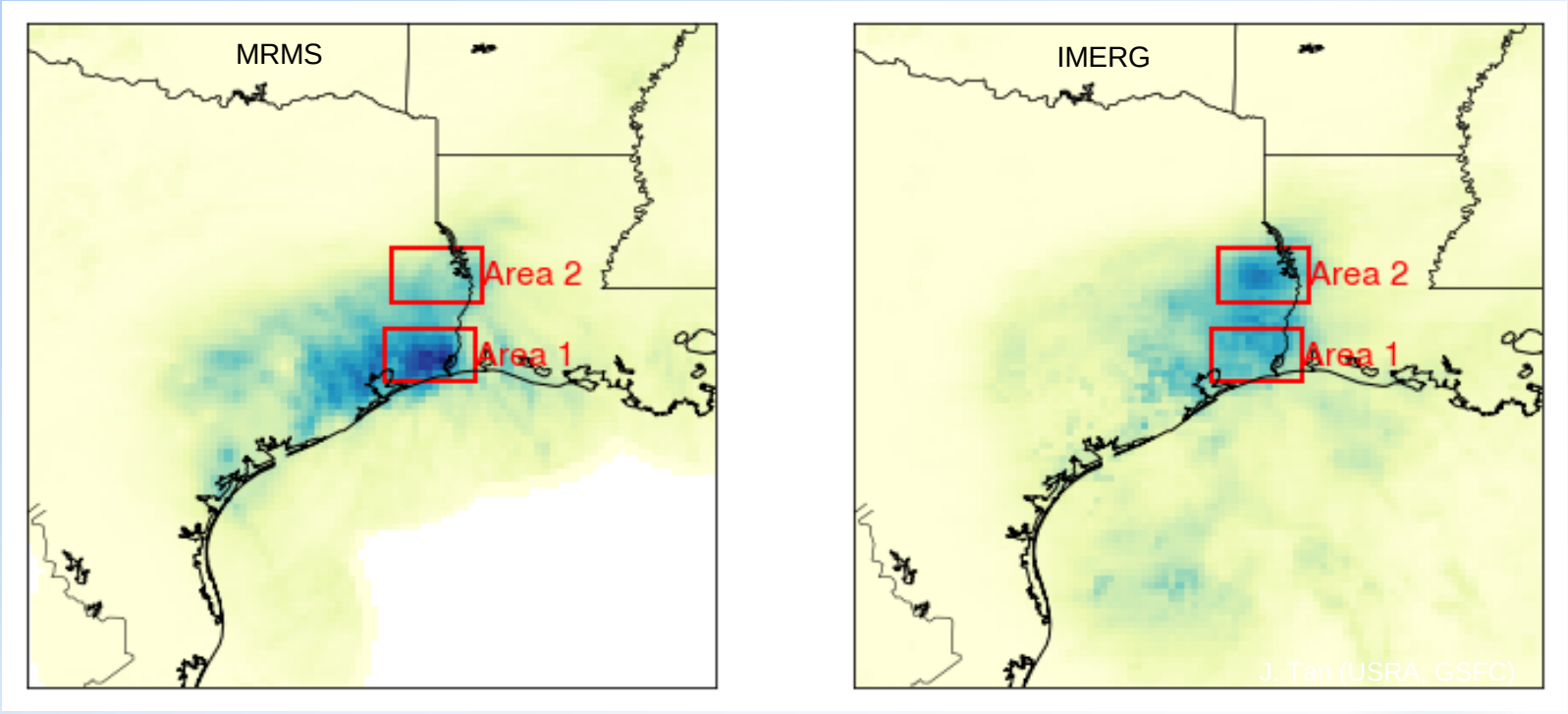
- first cut at the adjustment to gauges that the final calibration in IMERG enforces
- biases in GPM products addressed in V05, but still low, still require GPCP



VALIDATION FOR V05 – HURRICANE HARVEY

Harvey loitered over southeast Texas for a week, 25-31 August 2017

- Multi-Radar Multi-Sensor (MRMS) considered the best estimate
  - over land
  - some questions about the details of the gauge calibration of the radar estimate
- Late Run IMERG V05 under(over)-estimated in Area 1(2)
- This presumably tells us about the meteorology



USING NUMERICAL MODEL DATA TO ESTIMATE MORPHING VECTORS (1)

A quick review of “old” morphing vectors

- CPC half-hourly, 4 km “even-odd” IR Tb datasets provide separate umbrellas for each geo-satellite
  - provide consistent same-satellite data from one half hour to the next
  - Tb’s are thresholded to approximate rain areas, leaving gaps in coverage (plus gaps due to data drop-outs)
- vectors set as spatial offset with maximum correlation between two consecutive half-hourly IR Tb fields (2.5° grid, 5° template)
- time and space interpolation fill holes in the field of vectors
- vectors are reduced to account for cirrus-level motions being faster than precip system motions
  - scaling factors are computed against radar motions in CONUS and applied globally

USING NUMERICAL MODEL DATA TO ESTIMATE MORPHING VECTORS (2)

Issue: In Fall 2017 it appeared unlikely that PPS could obtain the necessary IR data to compute morphing vectors in the TRMM era

Solution: Move up the plan to test computing the morphing vectors with numerical model data

- use MERRA2 reanalysis data for non-real-time computations
- use GEOS5 forecast data for real-time computations
- the dynamics, parameterizations, and grid framework are the same for both
- both are produced by GMAO (in the same Division as the NASA IMERG team, facilitating easy communication)
- selected fields are available hourly at "full" spatial resolution (0.5° x0.625° for MERRA2, 0.25° x0.3125° for GEOS5)

Shifting to model-based vectors

- tested several MERRA2/GEOS5 hourly parameters
  - total precipitable water vapor (TQV) performed best
  - also tested surface precipitation, total precipitable ice water, total precipitable liquid water

USING NUMERICAL MODEL DATA TO ESTIMATE MORPHING VECTORS (3)

Vectors extend to the poles, enabling morphing over a fully global domain

Distortion of gridboxes near the poles is an issue

- short-term fix in lat./long. coordinates
- in V07 need to adopt a better grid system (Cubed Sphere? Tessellated Sphere?)

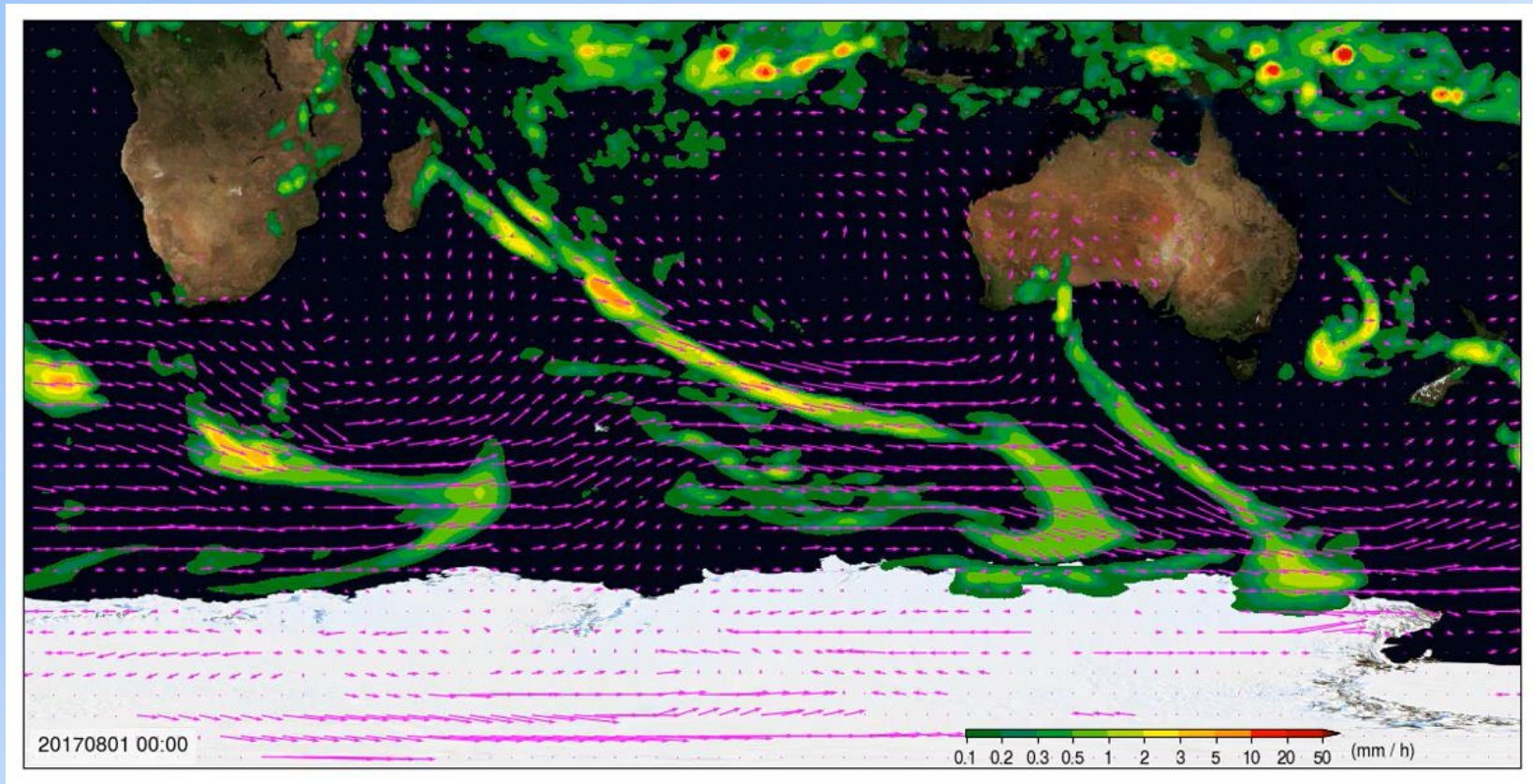
IMERG currently sets PMW precipitation over snowy/icy surfaces to “missing” due to quality issues

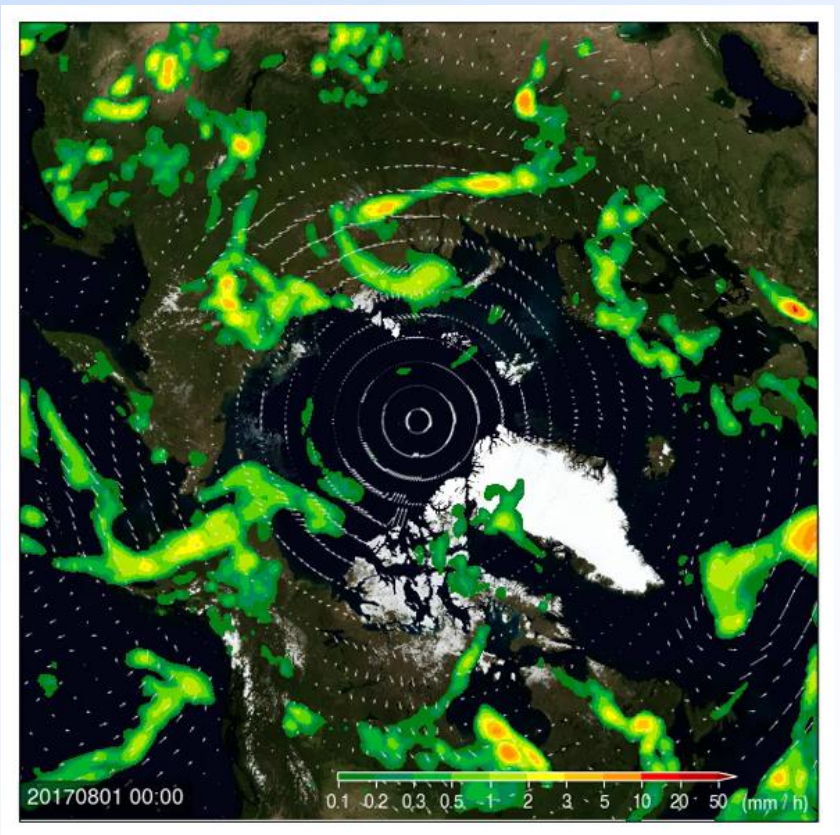
- no IR precipitation beyond 60˚ N-S, so precipitation is marked as “missing” over frozen surfaces at high latitudes
- alternative precipitation data source are under study for high latitudes

Vectors computed on the 2.5˚ grid are interpolated to the IMERG 0.1˚ gridboxes to enable smoother motion

No CONUS-radar-based scaling factors are applied

Example of TQV Motion Vectors and MERRA-2 Precip

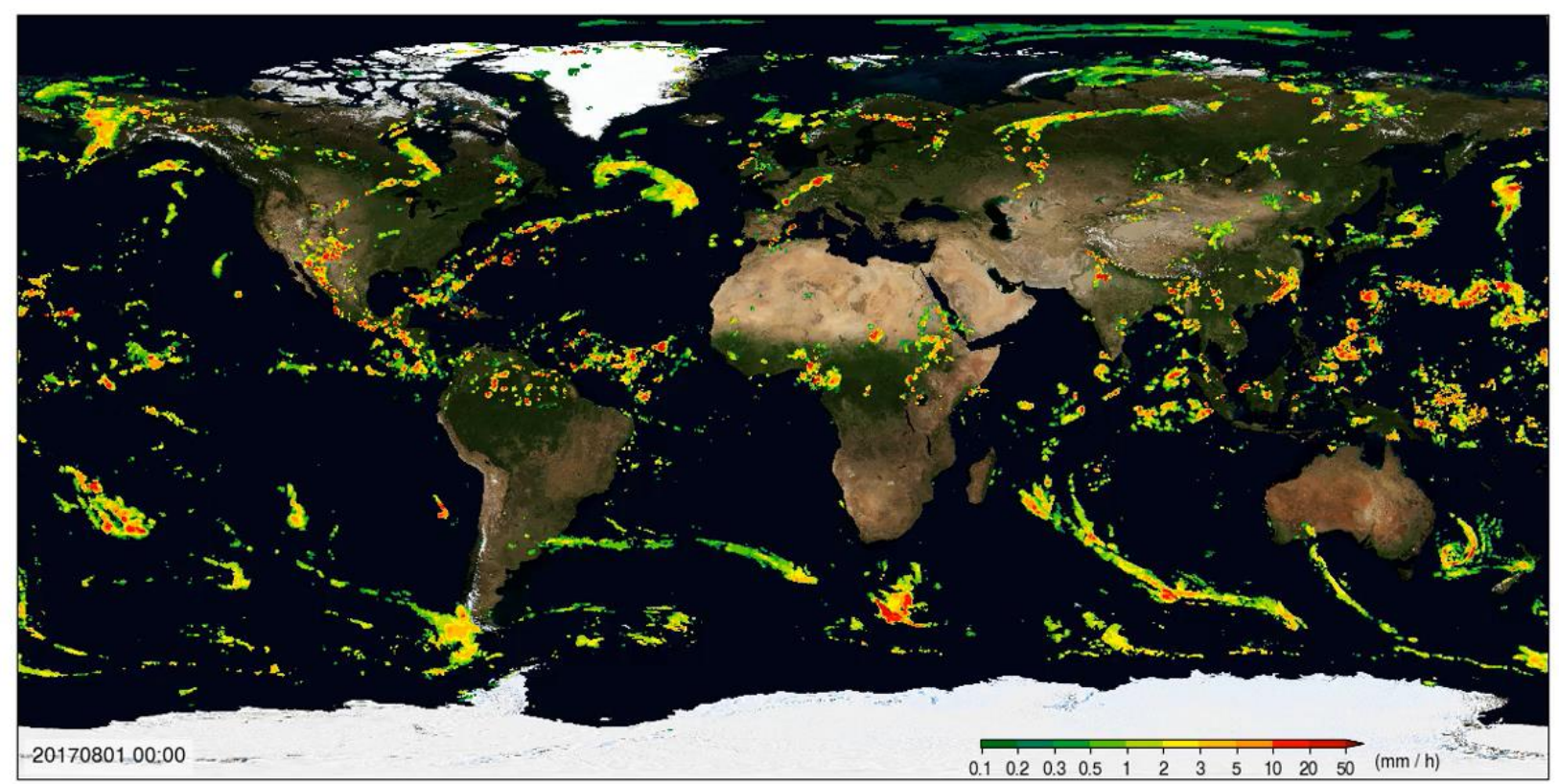


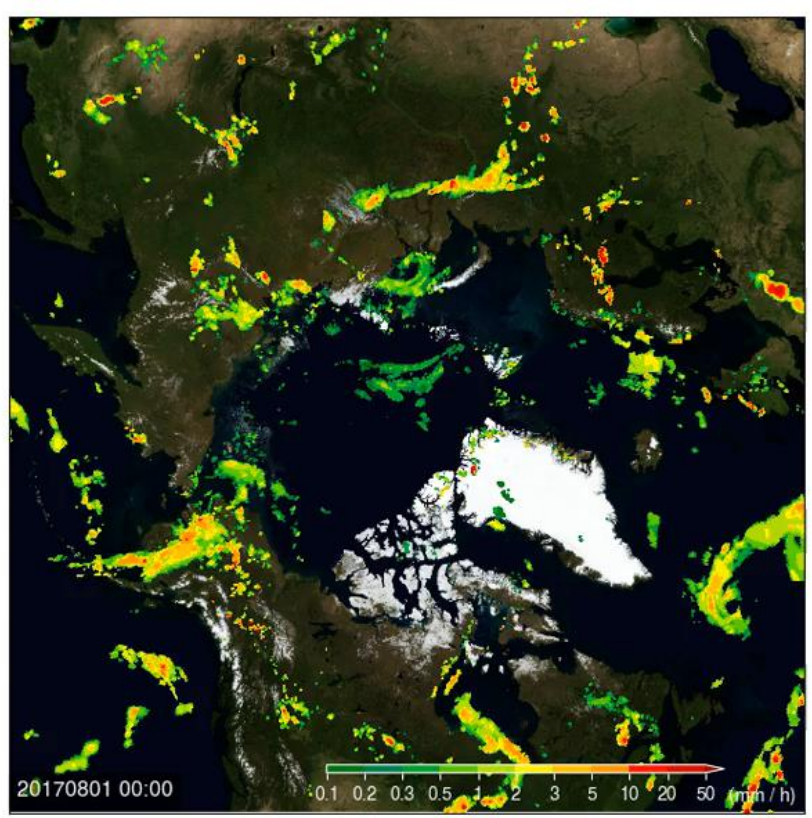


Colors: MERRA-2 precipitation
Arrows: vectors from TQV at 2.5°

Only have to trust TQV pattern motions, *not* actual values

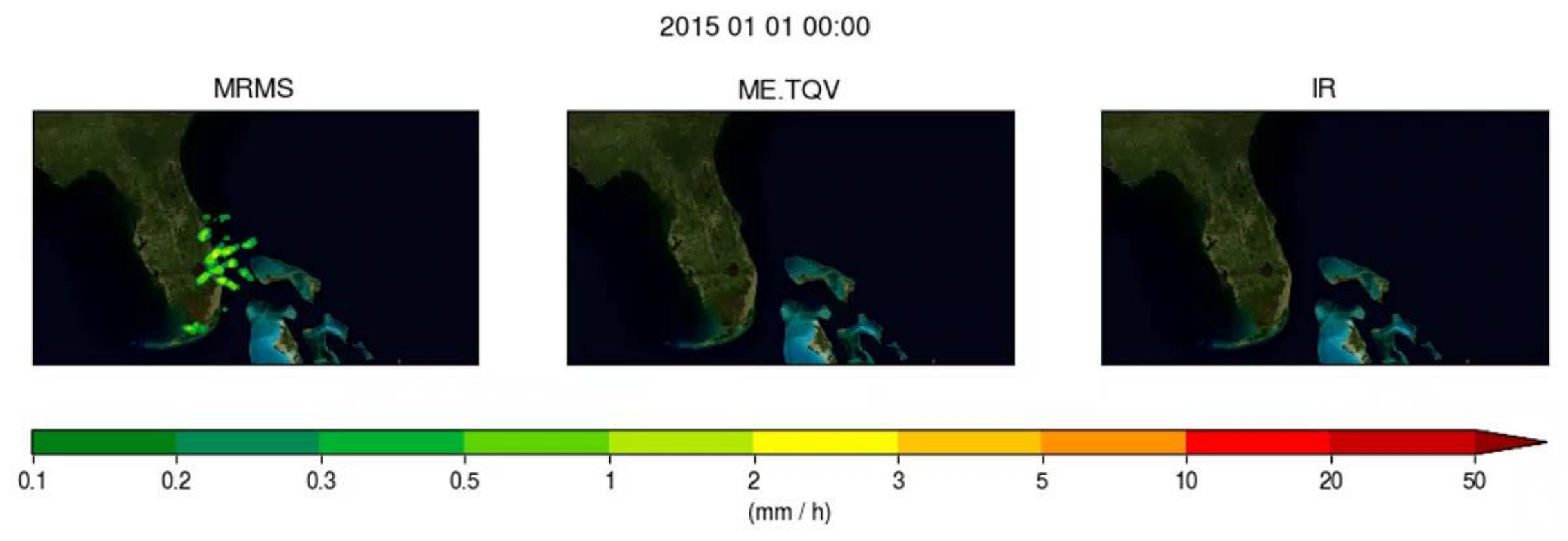
Example of TQV Motion Vectors Moving Passive Microwave Precip





Note: precipitation over frozen surfaces will eventually be masked.

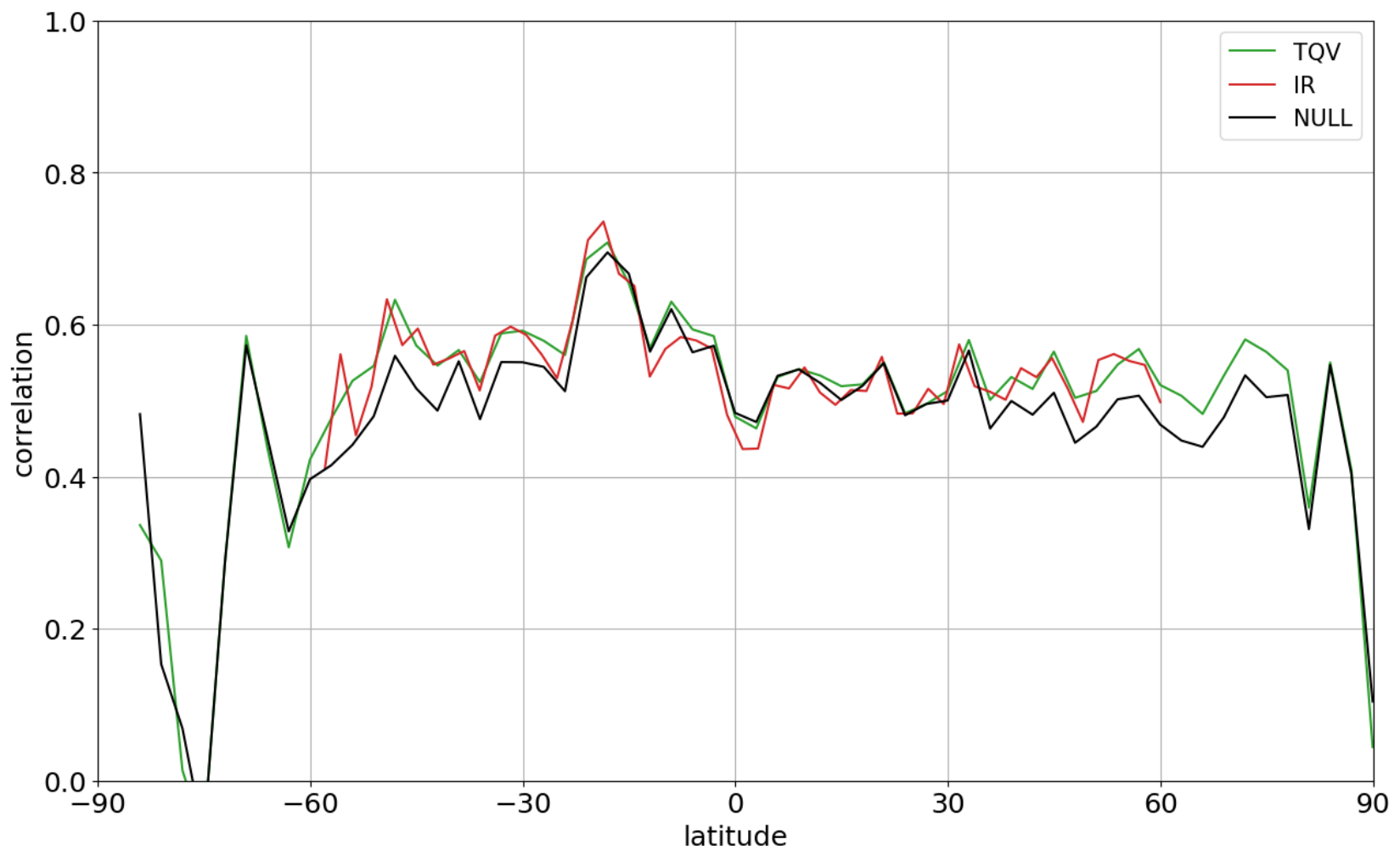
Case Study: Florida (Forward Morphing Only)



IR is driven by high-level cirrus.

TQV is better able to capture the correct motion.

Zonal Mean Correlation (August 2017)

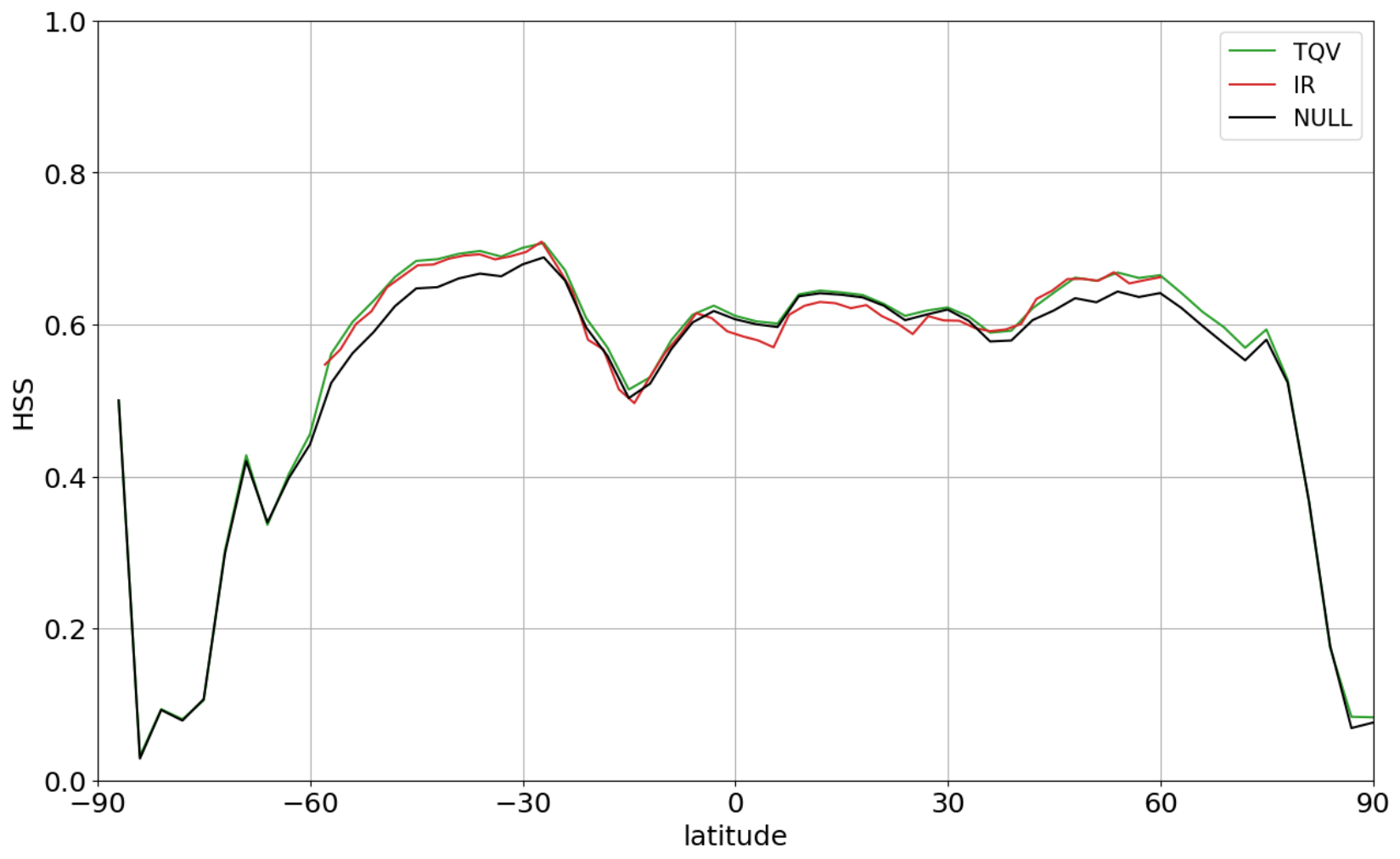


Global average (60°N/S):
- TQV: **0.551**
- IR: 0.543
- NULL: 0.520

Ocean (60°N/S):
- TQV: **0.588**
- IR: 0.578
- NULL: 0.553

Land (60°N/S):
- TQV: **0.454**
- IR: 0.448
- NULL: 0.428

Zonal Mean Heidke Skill Score (August 2017)



Global average (60°N/S):
- TQV: **0.645**
- IR: 0.637
- NULL: 0.622

Ocean (60°N/S):
- TQV: **0.645**
- IR: 0.636
- NULL: 0.621

Land (60°N/S):
- TQV: **0.643**
- IR: 0.638
- NULL: 0.626

Schedule and Future Activities

Fall 2017: Version 05 IMERG, March 2014–present

- DPR calibration change
- “minor”, but important upgrades to other algorithms
- IMERG Quality Index
- still no morphing outside 60° N-S

Late summer 2018: TRMM V8/GPM V06 TRMM-based IMERG archive, 1998-2014

- changes to DPR and Combined, and to morphing require upgrade to V06
- GPM era will be upgraded to V06 after TRMM era is done

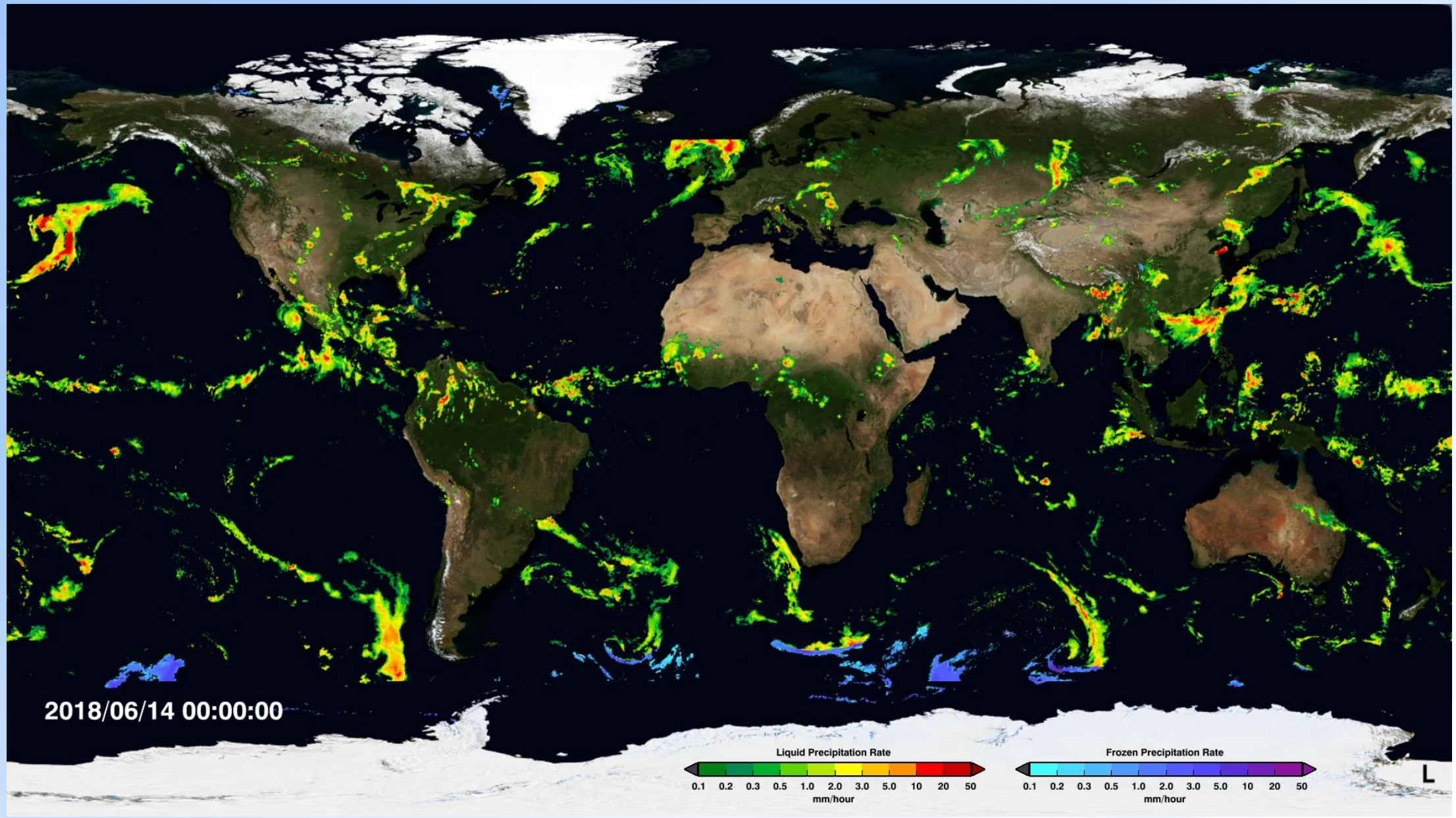
Fall 2018: GPM V06 GPM-based IMERG archive and ongoing processing, 2014-present

Early 2019: Legacy TMPA products retired

~2 years later: Version 07

- expand to fully global morphing
  - pursue a nearly equal-area computational grid
  - seek additional datasets that provide credible high-latitude precip estimates
- shift to modern wind-loss corrections to precipitation gauge data
- develop better error estimators and alternative Quality Index parameters
- develop a joint model-observation product (in addition to the current observation-only scheme)
- examine alternatives to the current IR scheme
- test the use of daily precipitation gauge analyses
- develop an IMERG Testbed to facilitate partnering with other researchers and groups
- accommodate shifts in input satellite precipitation algorithms and dataset availability

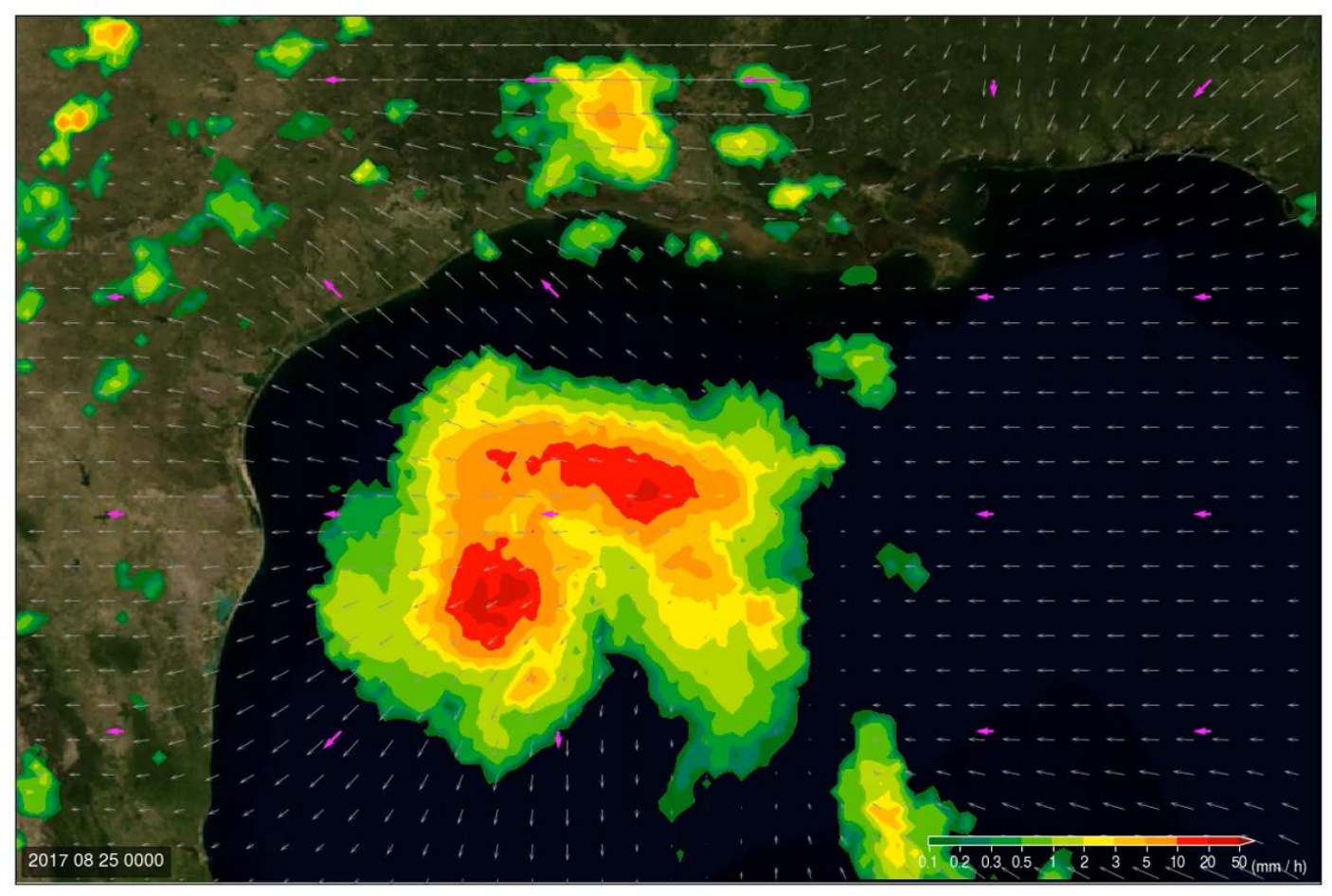
IMERG Near-Real-Time Run for 20-27 Mar 2018



http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4285

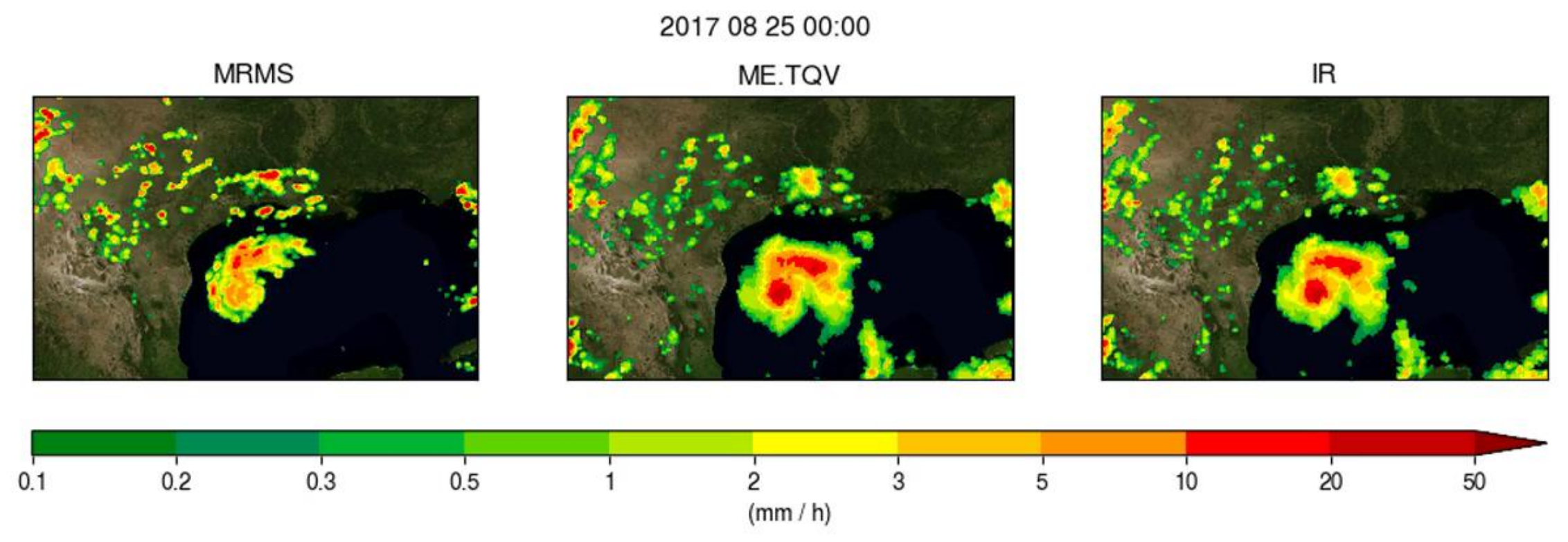
Extra slides

Vector Interpolation for Smoother Motion



- Motion vectors are computed at 2.5°, will then be **linearly interpolated** to each 0.1° precipitation pixels.
- This leads to **smoother motion**. Video shows Hurricane Harvey:
  - color: morphed precipitation
  - purple arrows: original vectors
  - thin arrows: interpolated vectors (showing only every 4th pixel)
- However, interpolated vectors are only as good as the original vectors.

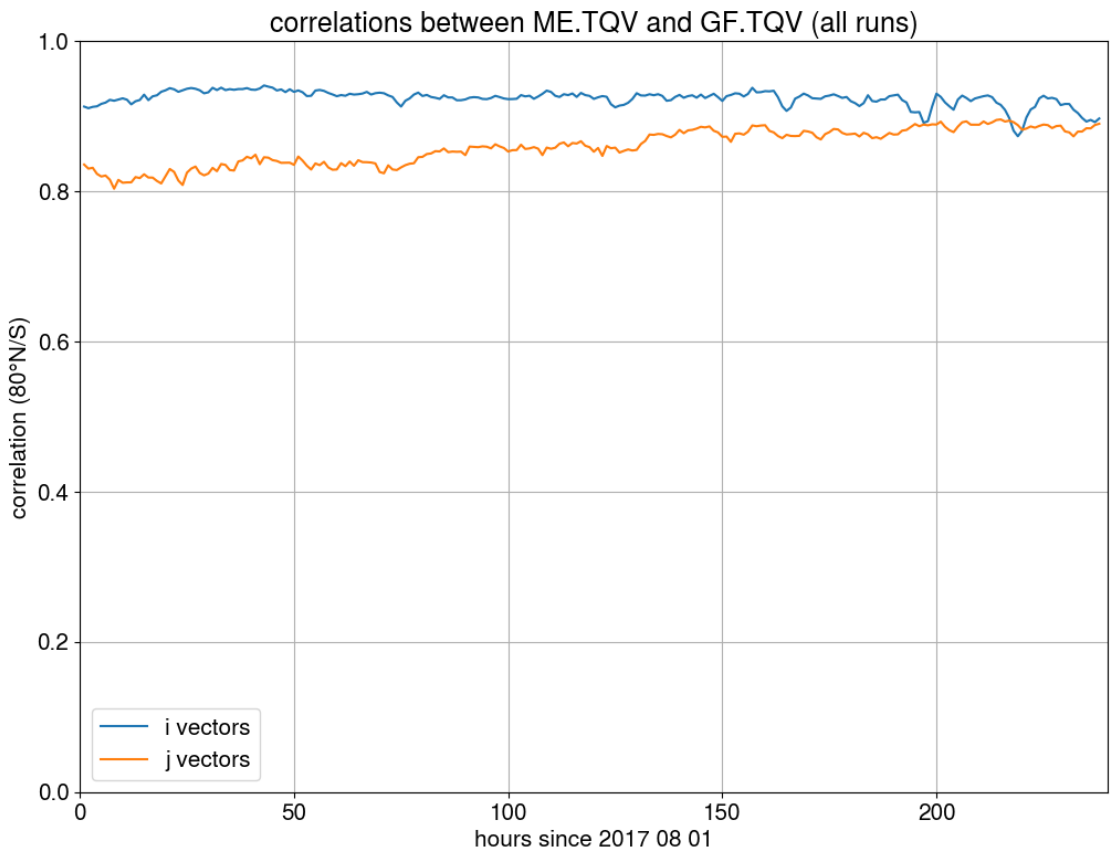
Case Study: Hurricane Harvey



Tightly rotating systems are slightly better represented, but there is room for improvements.

IMERG NRT: GEOS-5 FP vs. MERRA-2 Vectors

MERRA-2 vs. the latest GEOS-5 FP runs



MERRA-2 vs. a single GEOS-5 FP run